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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 734
Joint Contribution from the Bureau of Markets, CHARLES J. BRAND, Chief, and the Bureau of Plant Industry, WM. A. TAYLOR, Chief.

Washington, D. C. ▼ November 13, 1918

NEMATODE GALLS AS A FACTOR IN THE MARKETING AND MILLING OF WHEAT.

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INTRODUCTION.

Wheat, as grown and harvested, contains numerous impurities, and much of it on reaching the merchant or miller contains foreign materials. As the buyer can not be expected to pay wheat prices for such material, a dockage or deduction is made commensurate with the amount and kind of foreign material present. Some of the impurities are readily removed from wheat, whereas others, which can be removed only with difficulty, such as cockle, wild peas, vetch, onions, rye, and ragweed seed, remain in the wheat and become serious factors in milling and baking operations. At many local points only one penalty is placed on the load of wheat, the dockage embodying all the factors likely to influence the future sale and milling of the wheat.

When wheat is to be purchased on grades as established by the Secretary of Agriculture under the United States Grain Standards Act,[1] this dockage determination is first made by an appropriate set of sieves in order to determine the quantity of wheat present. A grade is then given the sample on this dockage-free basis, taking into consideration such factors as moisture, weight per bushel, damaged kernels, foreign material other than dockage, as well as presence of smut, live insects, and odors. The list of foreign material other than dockage now is quite large, and any further addition must be viewed with some concern on the part of the merchant or miller.

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[1] U. S. Dept. of Agriculture Service and Regulatory Announcement (Markets), No. 33: Official grain standards of the United States for wheat, and official grain standards of the United States for shelled corn. 1918.

A comparatively new source of foreign material not previously encountered in marketed wheat has lately come to the attention of the Department of Agriculture; this, if not controlled, will figure conspicuously both as dockage and foreign material other than dockage in grain. This is a black, misshapen gall resulting from the infection of wheat heads by the nematode *Tylenchus tritici* (Steinbuch) Bastian. This foreign material, as far as known, has not been recognized by grain inspectors in the commercial grading of wheat. Investigations up to the present time indicate that the disease has a rather limited distribution and there is as yet little evidence to indicate whether it will prove to be a serious factor in wheat growing in other parts of the country.

On account of the number of places where this disease seems to be established, it was thought necessary to bring the disease to the attention of merchants, millers, and wheat growers in order that they might easily recognize it, have some knowledge of its present distribution, its importance as a factor in affecting market grades and milling quality; also to give some information concerning its control in order that it may be eliminated efficiently and quickly as a serious pest in wheat.

PREVIOUS OCCURRENCE OF THE DISEASE.

This disease has been known as a serious pest in Europe since 1745. Has been found in Australia, Austria-Hungary, Germany, Holland, Sweden, Switzerland, and very recently in China. Previous citations as to its occurrence in this country are few. Bessey[1] has noted related forms in various grasses, but did not observe any form attacking wheat. Johnson[2] seems to have first noted its distribution in this country, having found it near Modesto, Cal., in May, 1909. He also reported finding it established in the States of West Virginia, New York, and Georgia. Byars[3] and Fromme[4] have reported it from China and Virginia, respectively.

PRESENT DISTRIBUTION.

The importance of this disease as a factor in the marketing and milling of wheat first came to the attention of the Bureau of Markets by a request for identification as a troublesome foreign material in some Virginia wheat. Observations showed the exhibits to be nematode galls resulting from plants infected with the nematode disease of wheat. These findings were confirmed by the Bureau of Plant Industry.[1]

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[1] Bessey, Ernst, A. A nematode disease of grasses. Science N. S. 21, 391, 1905.

[2] Johnson, Edward C. Notes on a nematode disease in wheat. Science N. S. 30, 576, 1909.

[3] Byars, L. P. *Tylenchus tritici* on wheat. Phytopathology, vol. VII, 56–57, Feb., 1917.

[4] Fromme, F. D. *Tylenchus tritici* on wheat in Virginia. Phytopathology, vol. VII, 452–453, Dec., 1917.

Further inquiry throughout the State of Virginia revealed the fact that this single occurrence was not an isolated one, but that the disease was established in various sections of the State in such magnitude as to affect seriously not only yields per acre but also the market grades and milling quality of wheat containing such material. At the present time these galls have been found in wheat or wheat screenings from merchants or millers in the vicinity of Bridgewater, Crofton, Charlottesville, Culpeper, Dayton, Dovesville, Edinburg, Grottoes, Harriston, Harrisonburg, Leesburg, Lacey Springs, Lexington, Linville, Lynwood, Lynchburg, Marshall, Mount Solon, Mount Crawford, New Market, Purcellville, Port Republic, Powhatan, Rural Retreat, Timberville, Union Mills, Weyers Cave, and Woodstock, in the State of Virginia.

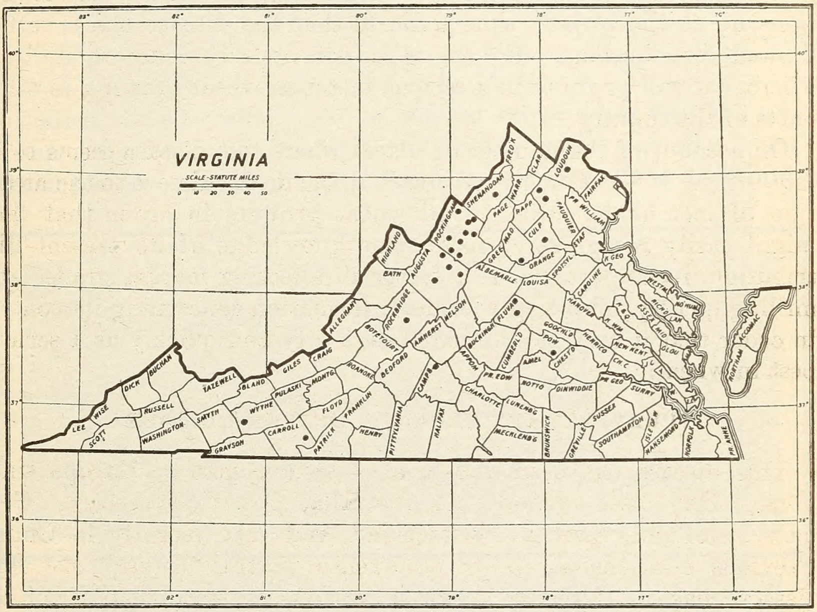

FIG. 1.—Showing places in the State where the diseased kernels have been found either in wheat or in screenings.

Through the courtesy of the Food Administration Grain Corporation approximately 3,500 samples of wheat have been analyzed from all the important wheat-growing sections in the United States. The results of these observations are given in Table 1.

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[1] In this connection acknowledgment is made of the work of Mr. L. P. Byars of the Bureau of Plant Industry.

TABLE I.—*Results of the analyses of commercial wheat samples for the presence of nematode galls.*

State where grown.	Number of samples.	Per cent of samples showing gall.	State where grown.	Number of samples.	Per cent of samples showing gall.
Arkansas	1	0	Nebraska	23	0
California	266	Trace.	New Jersey	1	0
Delaware	8	0	New York	44	0
Georgia	3	0	Ohio	204	0
Kentucky	1	0	Oklahoma		0
Illinois	172	0	Oregon	4	0
Indiana	91	0	Pennsylvania	127	0
Iowa	3	0	North Dakota	193	0
Maryland	201	0	South Dakota	83	0
Michigan	85	0	Virginia	108	11
Minnesota	163	0	West Virginia	52	0
Mississippi	1	0	Wisconsin	1	0
Missouri	223	0	Not known	1,000	0
Montana	163	0			

No samples were found outside of the States of California and Virginia having wheat infected with these nematode galls, and it would seem at the present writing that the disease is confined mostly to the State of Virginia. Eleven per cent of the samples of the Food Administration from Virginia showed the galls to be present to a greater or less degree. One of the California samples had galls present in the dockage determination separation.

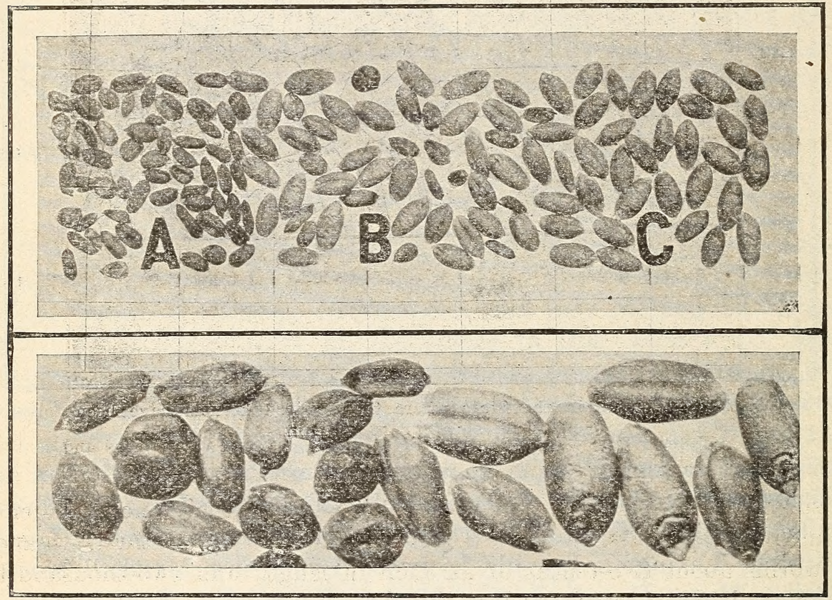

FIG. 2.—*A*, Nematode galls; *B*, wheat containing an admixture of galls; *C*, wheat for comparison with *A*. Lower, galls and wheat enlarged 3×.

DESCRIPTION OF THE GALLS AND DISEASED PLANTS.

The galls which have been photographed and are shown in figure 2 in comparison with sound wheat are irregular in shape, shriveled, and wrinkled. Usually they are shorter and broader than sound wheat kernels, but sometimes are equal in size, or again may be very narrow and needlelike. Very small galls, the size of wild buckwheat, are also found frequently. It is not uncommon to find several of them tightly cemented together.

In color the galls vary from a light gray to a jet black. Usually they are dark brown but may also be mottled to some extent.

The covering of the gall is very thick, making up some 95 per cent by weight of the entire gall. It incloses a yellowish-white powdery substance, which, when moistened with water and placed under a magnifying glass, is seen to disintegrate into small thread-shaped worms about two-tenths of an inch in length and two-thousandths of an inch in width and slightly decreasing in size at each end. Figure 3 is a transverse section of one of the galls magnified to show the thick covering and the inner powdery substance composed mostly of small worms.[1] Figure 4 is a photograph of one of the nematodes or eel worms highly magnified to show its structure.

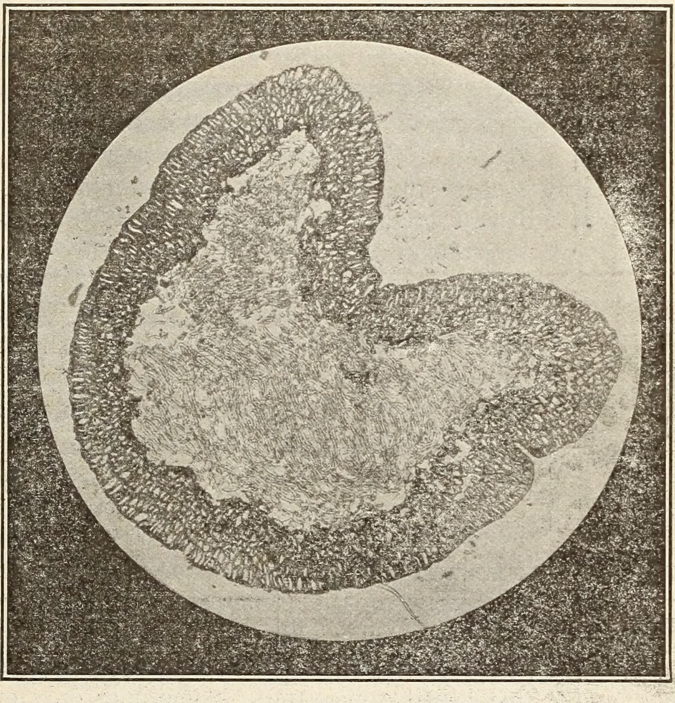

FIG. 3.—A transverse section of the nematode gall, showing worms and outer thick husk. X 35

The galls, upon falling to the ground, decay under favorable moisture and temperature conditions. The nematodes then escape, and, migrating through the soil, attack the wheat seedlings, penetrating between the leaf sheaths, causing them to become wrinkled, distorted, and swollen. The larvæ so adjust their zone of infection that almost all remain near the young growing portion of the plant. In this way, as the plant grows they are elevated toward the flowering parts. When the plant blossoms, the larvæ, which up to this time appear not to have taken nourishment, enter the flowering parts, from which they obtain food. Here they develop sexuality, pair, lay eggs, and die. These eggs hatch and produce larvæ. When the wheat plant matures these larvæ become coiled and dried up, forming the inner yellowish-white portion of the black gall as is shown in figure 5. The nematodes have great tenacity of life, and in many respects are analogous to the well-known *Trichinae* of pork. They bear a temperature of 125° F. and are also very resistant to frost and low temperature.

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[1] The Bureau of Markets wishes to express its gratitude to Miss B. H. Silberberg, Bureau of Chemistry, for the photomicrographs of figures 3 and 5.

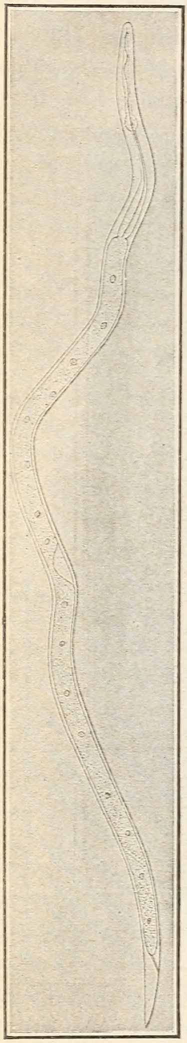

FIG. 4.—The nematode *Tylenchus tritici.* ×150

Heads infected with the nematode disease resemble heads infected with the stinking smut of wheat. They are usually thicker and shorter than normal heads, the glumes of the spikelet are spread somewhat, and in place of the normal seed, dark galls, incapable of germination and full of larvæ, are to be found.

Information gathered from those whose crops of grain have been infected with this disease is to the effect that it is easily recognized in the field on account of the darker green appearance of the heads and their somewhat longer maturing period. The plants are smaller, having a blighted and blackened appearance. Sometimes only one side of the spike is affected, while the other side is normal. There may also be some sound grains in the infected spikelet, and in some instances the head may not be infected at all, the only apparent infection being the formation of tumor-like or abcess-like elevations on the leaves of the plant. Figure 6 shows the similarity between wheat heads infected with the nematode disease and with the stinking-smut disease of wheat in comparison with an unaffected wheat head.

Soil conditions seem to have an important bearing on the disease. Spots in fields which become water-logged, or parts of the field where trash has accumulated, show the greatest percentage of infected plants.

Farmers and mill operators who were questioned about this disease stated that it had been known to them for varying periods of from 5 to 20 years. They had known it under such names as hard smut, cockle, bin-burned wheat, frosted kernels, and immature wheat. As a matter of fact these galls are quite different. In figure 7, where they are pictured in contrast, they can be easily distinguished from bin-burned wheat, frosted wheat, smut, and corn cockle.

Smut can be distinguished readily from these galls by crushing under the thumb. Smut balls can be crushed in the hand and leave the hand covered with a mass of black, evil-smelling material. It is almost impossible to crush nematode galls on account of their hardness. Some conditions of smut, i. e., hard smut, may be mistaken for these galls, but if cut open will at once show the absence of the inner yellowish-white portion, which is a distinguishing feature of the nematode galls.

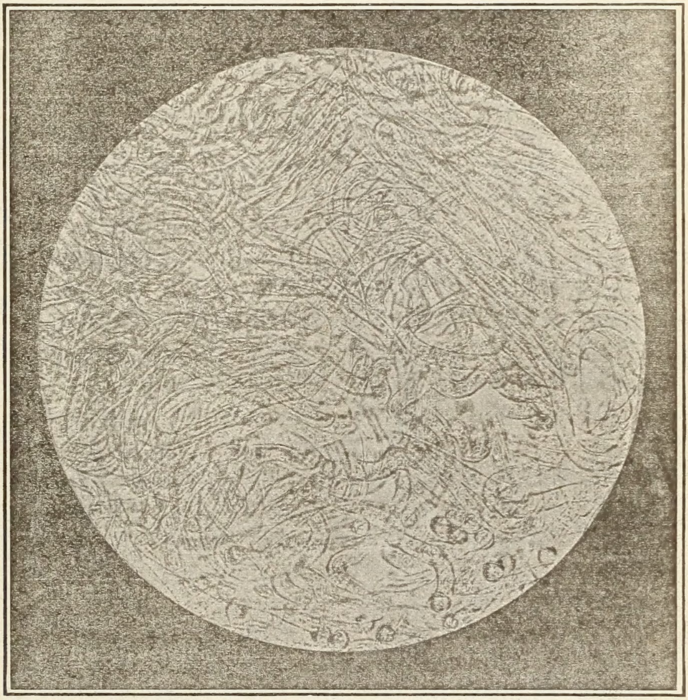

Fig. 5.—A portion of the inside of the gall magnified to show the coiled nematodes.

Cockle is easy to distinguish because of the spiny appearance of its seed coat. Bin-burned wheat frequently has been confused with these galls. It may be distinguished from nematode galls, however, because the shape of the bin-burned wheat kernel remains intact in spite of the decoloration. This is not true of nematode galls, which are very irregular in shape. The powdery substance present within the gall is not found in bin-burned wheat.

A FACTOR INFLUENCING MARKET GRADE AND MILLING QUALITY.

In samples of grain obtained from millers and farmers throughout the State of Virginia these galls were found in amounts varying from 0.1 per cent to 25 per cent. As a grading factor this is extremely important, as the galls must be classed as foreign material and calculated as dockage if they can be removed readily from the

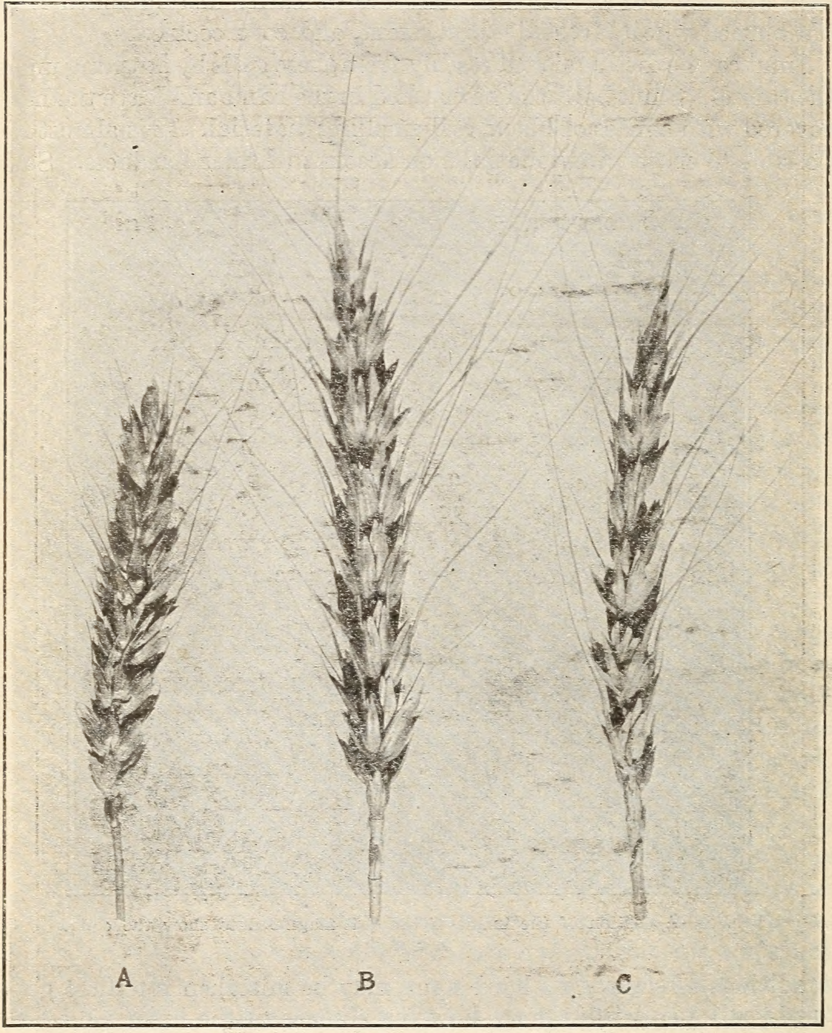

FIG. 6.—Showing the comparison between heads infected with the nematode disease and the stinking-smut disease of wheat. *A*, head infected with nematodes; *B*, sound head; *C*, head infected with stinking smut.

wheat, or as foreign material other than dockage if they can not be removed in the determination of dockage.

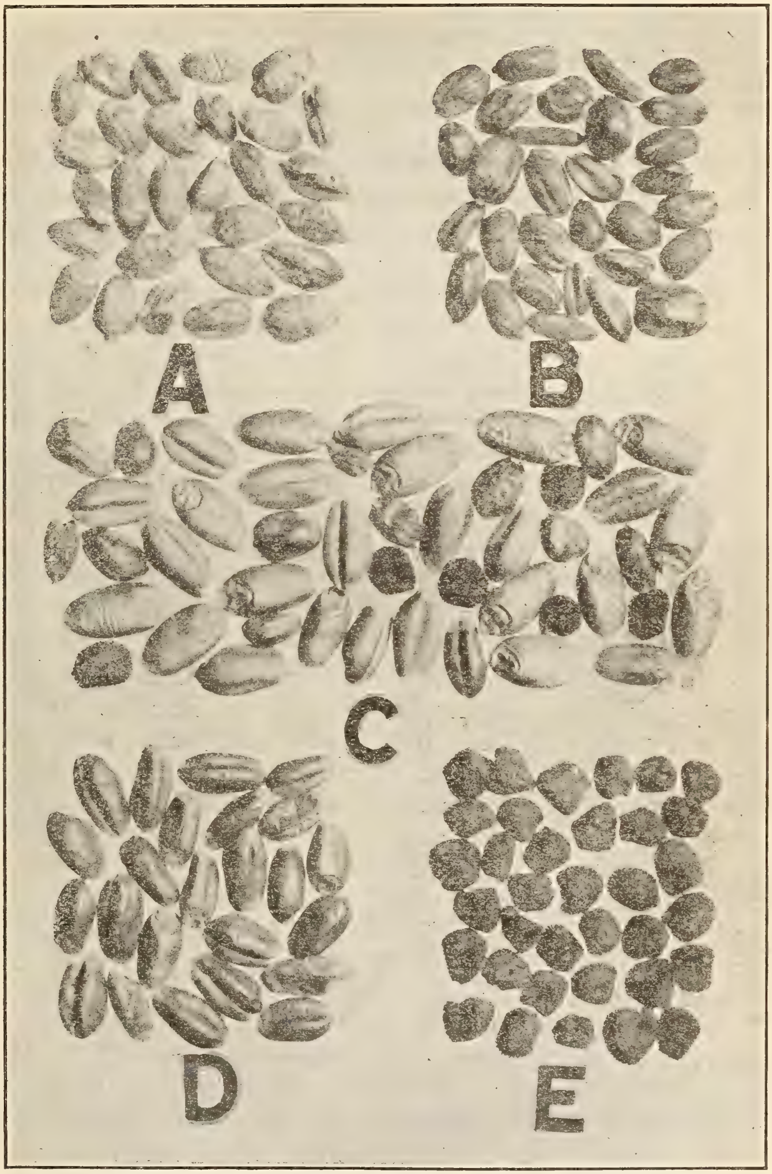

FIG. 7.—*A,* Smut balls; *B,* nematode galls; *C,* wheat containing smut, corn cockle, bin-burned wheat, and nematode galls; *D,* bin-burned wheat; *E,* corn cockle.

The estimation of the foreign material in wheat is generally made in one of two ways.[1] It may be made by means of sieves such as are described as in use by the Department of Agriculture under the United States Grain Standards Act, or it may be estimated by means of the so-called wild-oat kicker.

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[1] U. S. Dept. of Agriculture, Farmers' Bulletin 919. The application of dockage in the marketing of wheat. 1917.

Experiments were made to remove nematode galls as separable foreign material (dockage) in the grain-standardization laboratory of the Bureau of Markets by both methods. Using the oat-kicking machine, only about one-eighth of the total percentage of the galls were removed as easily separable foreign material, the others remaining behind in the sound wheat. By means of the standard sieves, i. e., the fine-seed sieve, the buckwheat sieve, and the small chess sieve, a somewhat greater percentage was removed. Even with these three sieves, however, from 65 to 70 per cent of the galls remained in the wheat as foreign material other than dockage.

Experiments were also made to remove the galls by vigorous fanning. By this method, with a fan revolving 850 times per minute, a still larger percentage was removed. Nevertheless 40 to 45 per cent of the total galls remained. With still harder fanning a greater quantity no doubt could be removed, but this would result in the removal also of a greater quantity of sound wheat.

Mills equipped with wheat washers and driers which are specially devised to clean smutty wheat can eliminate these galls almost entirely by floating them out, as they are lighter than sound wheat, with a specific gravity of 0.8125.

From a grading standpoint the presence of these galls in the grain also reduces the weight per bushel, an important item in determining the grade of grain. It is readily seen that a farmer with such galls in his load of wheat will be subjected to heavy penalties. First, the separable foreign material is assessed as dockage, and later the grade may be reduced because of the remaining foreign material other than dockage.

Knowing the pathological significance of these kernels, the question might also be raised whether such wheat should not be regarded as similar to wheat infested with garlic, onions, weevil, or smut, and placed in a class by itself.

The amount of flour which can be obtained from a bushel of wheat is of prime importance to a miller, since flour is the most valuable mill product. Any impurity which reduces the yield of flour obtained in milling wheat or lowers the quality of the flour has a direct bearing on the milling value and should receive consideration in the grading of the wheat. Any factor which appreciably injures the color of flour will result in a product of low grade or in a reduction of the purchase price.

Chemical analysis of the nematode galls by the Bureau of Chemistry is given below in comparison with an analysis of sound wheat berries. For comparative purposes both have been reduced to the water-free basis.

TABLE 2.—*Chemical analysis of nematode galls in comparison with sound wheat berries.*

Chemical constituents.	Nematode galls.	Sound wheat.
	Per cent.	*Per cent.*
Ether extract	6.9	2.06
Crude fiber	22.2	2.68
Protein	21.3	13.70
Ash	3.4	2.06
Nitrogen-free extract	46.2	79.00
Pentosans	20.4	....
Sugars	....	....
Acidity, c. c. $\frac{N}{1}$ alkali per kilo	110 c. c.	12 c. c.
Dry gluten	None.	11.8
Moist gluten	None.	28.8

An examination of the chemical analysis of the nematode galls shows that the nitrogen-free extract, which in the normal wheat berry consists mostly of starch grains, has been greatly reduced. On the other hand, the crude fiber, crude protein, ash, and fat have been largely increased. The normal acidity of the whole wheat berry has likewise been raised ten times above that present in sound wheat. It would seem that the percentages of these other components of the wheat berry had increased at the expense of the lesser amount of nitrogen-free extract, or carbohydrate. Microscopic tests for starch grains showed them to be almost completely absent. Whether the nematodes consumed the starch or whether their presence in the plant resulted in physiological disturbances precluding starch formation is difficult to say.

The fact that the nematode galls contain no starch is very important. The lack of starch grains will necessarily result in a lower flour yield from any given quantity of wheat, with the nematode galls present. The presence of the galls in wheat will increase the percentage of the lower-grade flours, because black specks, which are portions of the gall coat, remain in the flour and discolor it.

Comparative milling and baking tests on a sample of wheat containing galls as obtained on the market with the same sample from which the galls were removed by hand picking is given in Table 3. This work was done at the grain-standardization milling and baking laboratory at Fargo, N. Dak.

TABLE 3.—*Milling and baking test of nematode gall infected wheat.*

Operation.	Wheat and galls.	Wheat galls removed.
Milling test:		
Weight per bushel—		
Uncleaned . . . pounds. .	56	55
Scoured . . . do. . . .	61	61.5
Screenings . . . per cent. .	5.5	5.5
Mill products—		
Straight flour . . . per cent. .	72.7	73.9
Shorts and low grade . . . do. . .	14.0	12.3
Bran . . . do. . . .	14.5	14.0
Gain . . . do. . . .	1.2	.3
Moisture at tempering . . . do. . . .	9.8	9.8
Before . . . do. . . .	9.8	9.8
After . . . do. . . .	14.6	14.1
Baking test:		
Flour used . . . grams. .	340	340
Water used . . . cubic centimeters. .	180	180
Weight of loaf . . . grams. .	483	484
Volume of loaf . . . cubic centimeters. .	2,080	2,010
Color . . .	79	93
Texture . . .	94.5	93
Crumb . . .	Dark gray.	Gray.
Remarks . . .	(1)	None.

[1] Noticeably unpleasant odor present throughout process.

Mr. L. M. Thomas, who conducted the tests at Fargo, writes:

> With ordinary cleaning machinery, where the separation of foreign material is accomplished by means of sieves and air currents, only a very small percentage of the nematode masses can be removed from the wheat. In the case of the sample milled, the original contained 2.7 per cent of infected kernels. After cleaning the sample by the process used in preparing all our samples for milling, the sample still contained 2.5 per cent of infected kernels, or 92.6 per cent of those in the original sample. The most satisfactory method perhaps of removing these nematode masses would be by floating them away from the wheat. In mills equipped for washing wheat, this could easily be done, but where there is no washing and drying system it is doubtful if any appreciable number of these infected kernels could be removed.

The results of the milling test also show slight variations. Less flour was obtained from the sample containing galls than from the hand-picked samples. The flour from this sample contained black specks resulting from the breaking up of the galls. There was likewise a correspondingly increased amount of shorts and low-grade flours. The baking test also brought out slight differences. The loaf made from the flour containing the ground-up galls was quite inferior in color and had a dark-gray crumb. Throughout the baking process a noticeably unpleasant odor was present with this sample. The texture and volume of both loaves, however, were not affected to any extent.

The temperature of the water used in tempering these samples was 62° F. In the tempering of samples for milling on the small experimental mill there is no application of heat or steam. In commercial mills there would often be a slight application of steam to the wheat just before it enters the rolls, the object being to toughen the bran.

It was thought that this temperature would be sufficient to kill all the larvæ, but Mr. Thomas states that it is quite unlikely that the small amount of steam used would penetrate any deeper than the outside coats of the berry. Of course, during the baking process, all larvæ would be killed, which were not killed in the milling operation. They are still present in a macerated condition, and it would seem for sanitary reasons that they should be removed.

Notice has also come to the attention of the Department of Agriculture that some farmers mill their own flour from this infected wheat. Knowing the content of these galls, this practice is repulsive, and it is recommended that in the future, wheat for home milling be carefully inspected for the presence of these nematode galls, and that they either be removed by floating or that such wheat be rejected or diluted with sound wheat until a negligible amount of galls is present.

METHODS OF CONTROL AND DISTRIBUTION.

It is apparent that if this disease is allowed to increase it will become a serious factor in the marketing and milling of wheat, and, therefore, known methods for its control should be made public at the present time.

Apparently, no previous extensive experiments have been carried out for the purpose of controlling this disease in this country. No doubt the prime essentials for effective control are clean seed and crop rotation. Past experiments indicate that the nematodes must have either the gall or the host plant present as a protection, otherwise they do not live long in the soil in the active state. Also, it seems to have been shown that, of the common field crops, this nematode seriously attacks wheat only. It would seem, then, that a crop rotation of two or more years would be effective in practically ridding a field of this pest.

The use of clean seed, either by the buying of new seed from outside sources or by the planting of seed which has been properly cleaned, has been shown to reduce the infection in a number of instances throughout the infected area.

A number of ways for cleaning the infected grain have been tried and suggested. Bessey suggests that grain containing these galls be given the hot-water treatment, as carried out for the stinking smut of wheat, in order to kill the nematodes. Cobb[1] mentions winnowing. Steeping in a 2 to 5 per cent solution of sulphuric acid for one-half to two hours as a means of ridding seed of these organisms has also been suggested.

It has been the experience of several farmers, as well as that of the Grain Standardization Laboratory, that the bluestone treatment for smut, i. e., seed immersed in a solution of copper sulphate (1 pound of copper sulphate to 4 gallons of water) for three minutes is not an effective method for killing the nematodes, because in this length of time the solution does not pass through the hard covering of the gall.

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[1] Cobb, N. A. Cited by Johnson.

The modified copper-sulphate treatment of soaking the seed for 12 hours in a solution of the strength 1 pound of bluestone to 25 gallons of water has not proved successful in killing these worms.

Experiments show that soaking seed in 0.6 per cent sulphuric acid for 24 hours is an efficient method of killing the contents of the gall. This sulphuric-acid treatment is so subject to variations in the hands of an inexperienced operator that it can not be recommended for treatment of seed infected with these galls, however, as the germination of the seed is greatly decreased.

The hot-water treatment for smut, which is described in Farmers' Bulletin 507,[1] and which consists essentially of immersing seed for 10 to 15 minutes in water at a temperature of 135° F., has likewise proved successful in killing the nematodes. This test, however, unless properly carried out, is also liable to injure the sound seeds and for this reason can not be recommended without reservation.

The most feasible method of removing the source of infection from sound wheat seems to be by floating the galls out in cold water. The nematode galls are lighter than sound wheat kernels, and this difference in weight is made use of in their separation. A suggested method follows:

Have two tubs or half barrels, one set above the other so that the overflow containing the galls will fall into the lower tub. Cover the lower tub with cheese cloth to catch the galls but let the water run through. Fill the upper tub with water to overflowing. Next pour the infected wheat into the top barrel slowly at the same time stirring vigorously. The galls and light chaff will rise to the top and float off when assisted by hand or skimmer, and will be caught on the cheesecloth over the lower tub. When vigorous stirring brings up no more galls pour or drain off the water. Air drying is accomplished quickly and easily if the wet grain be spread out to dry on a canvas or on a clean barn floor. The dampened grain should not be allowed to lie in a heap as the kernels will not dry out regularly; some will sprout and danger of heating is present.

The seed may be planted as soon as it will run freely in a drill or may be dried thoroughly and stored for future use. Experiments carried out by this method have resulted in the removal of over 99 per cent of the galls. It is recommended that the grain be allowed to remain in the water for only as long as absolutely necessary for a thorough removal of the galls or the germination will be affected.

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[1] Johnson, Edward C. The smuts of wheat, oats, barley, and corn. U. S. Dept. of Agriculture, Farmers' Bulletin 507. 1912.

To summarize, clean seed obtained from outside sources, or seed cleaned by means of floating the galls out of the infected wheat with water, combined with crop rotation, seem to be the most effective methods of controlling this disease at the present time. Experiments in which the Bureau of Markets is cooperating are now being conducted by the Bureau of Plant Industry on additional methods for controlling this disease, the results of which will be reported in the future.[1]

The disease propagates easily. This has been brought out several times from the investigations carried on throughout the infected area. One method of propagation is the planting of infected seed wheat. For example, one particular crop which contained these galls was sold for seeding purposes. Without exception the next season every farmer who purchased this seed had an infected crop regardless of the fertile condition of the soil. Farmers who planted their own infected seed harvested each year a greater proportion of galls. The highest proportion of galls to sound wheat coming to the attention of the Department of Agriculture was 25 per cent.

Some of the mills which do a seed-cleaning business as a side line return the screenings to the owners to be used for feed. If these screenings contain nematode galls and are given to fowls and stock for feeding purposes they constitute an important means of spreading the disease. Feeding experiments[2] indicate that the gall is not digested in all cases, but finds its way into the manure intact. When this manure is spread over the land the land is thus inoculated with these nematode galls, and if wheat is again planted two sources of infection, the seed and manure, are acting to supply infectious material for the young seedling. It is apparent that such screenings should be burned even at chance of losing some feed. The material removed from infected wheat by floating should also be burned as a precaution against further distribution of this disease.

Further experiments on this disease from a milling, grading, and distribution standpoint are now being carried forward by the Bureau of Markets in order that a better knowledge of the commercial importance of this material as a foreign material in wheat may be obtained.

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[1] U. S. Dept. of Agriculture, Office of the Secretary, Circular 114. A Serious eelworm or nematode disease of wheat. 1918.

[2] Marcinowski, K. Parasitich und semiparasitsch an Pflanzen lebende Nematoden. K. Biol. anst. F. land un forstw. Arb. bd., 7 hft. 1, p. 1–192, pl. 1, Berlin, 1909.

SUMMARY.

The results of this preliminary investigation show that a disease of wheat comparatively new to this country and to the grain trade is established in certain areas of the United States, particularly in certain sections of Virginia. This disease not only reduces yields per acre but also seriously affects market grades and milling qualities of marketed wheat, on account of the presence in the grain of a peculiarly misshapen black gall, which can be removed only with difficulty and which is the resting place of the invading organisms.

The presence of the galls in a parcel of wheat reduces the market grade in several ways. Its presence reduces the test weight per bushel because of its lighter weight. It also increases the amount of dockage and particularly the amount of foreign material other than dockage in any given lot of infected grain.

Flour yield from such infected wheat is reduced, and the percentage of low-grade flour and shorts is increased. Ordinary wheat-cleaning machinery will not remove these galls successfully, although machinery for washing and drying wheat will no doubt be successful.

The best known methods of control are crop rotation and clean seed. To kill the nematode larvæ, infected seed may be treated by the hot-water treatment used for the control of smut to kill the nematode larvæ. The easiest method and the least dangerous practice to obtain clean seed is to float the galls away from the sound wheat by means of water.

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